High Resolution Model Simulations for C3VP, MC3E, and IFloodS: Comparison with Observations

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Objective

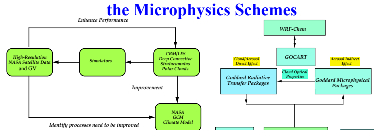
To use measurements from Global Precipitation Measurement (GPM) Ground Validation (GV) field campaigns (C3VP, MC3E, LPVEx, IFloodS and IPHEX) to evaluate performance of the NASA cloud resolution models.

To conduct real time forecast (MC3E, IFloodS, and IPHEX) using NU-WRF.

To validate the Goddard microphysics schemes (including 4-ICE and spectral bin scheme) for a wide range of precipitation systems (e.g., scattered versus organized convective systems and lake effect versus synoptic snow events) in different geophysical locations (e.g., Iowa, Oklahoma, and Canada).

To provide model simulated cloud and precipitation data for GPM algorithm developers.

Continue testing and improving the Microphysics Schemes



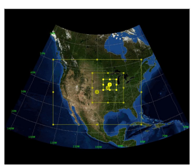
Models need: DSDs at various layers (gamma or exponential distributions for cloud water, rain, cloud ice, snow, and graupel), **3D liquid and ice water contents** and median **diameters**, mixed phase information, particle **number concentrations** for cloud ice, snow, graupel and hail, **aerial ratios (ice habits)**, and the liquid water fraction of melting snow, graupel and hail, over the **life cycle** of clouds and cloud systems

NASA Unified WRF (NU-WRF)
http://nuwrf.gsfc.nasa.gov

Peters-Lidard, C.D., E. M. Kemp, T. Matsui, J. A. Santanello, Jr., S. V., Kumar, J. Jacob, T. Clune, W.-K. Tao, M. Chin, A. Hou, J. L. Case,, D. Kim, K.-M. Kim, W. Lau, Y. Liu, J.-J. Shi, D. Starr, Q. Tan,, Z. Tao, B. Zaitchik, B. Zavodsky, S. Zhang, M. Zupanski (2014), Integrated Modeling of Aerosol, Cloud, Precipitation and Land Processes at Satellite-Resolved Scales with the NASA Unified-Weather Research and Forecasting Model,Environmental Modelling & Software (accepted).

Website for mesoscale modeling group and cloud library
http://cloud.gsfc.nasa.gov/

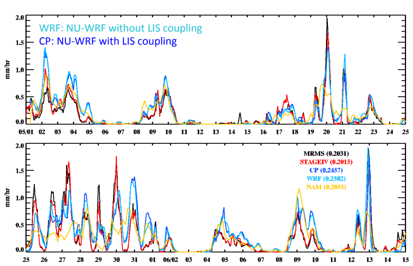
IFloodS Real-time Forecast



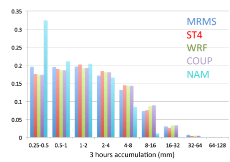
Three domains (**9km, 3km, 1km**) with **60 vertical layers.**

Physics schemes: Goddard Microphysics scheme, Grell-Devenyi ensemble cumulus scheme, Goddard Radiation scheme, MYJ planetary boundary layer scheme, Noah surface scheme, Eta surface layer scheme, NAM (18km) as input

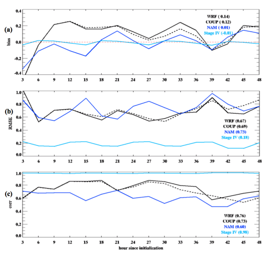
Computational Cost: **2048 CPUs, takes 7 hours to produce 48 hours forecast.**



NU-WRF has overestimated rainfall. NAM has some difficulties in forecasting rainfall events during 5/25-6/3.



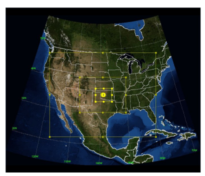
- All datasets are on 12 km grid.
- NAM overestimate light rain frequency, but underestimate heavy rain frequency.
- Two NU-WRF runs have very close PDF distribution.



WRF (solid): NU-WRF without LIS
COUP (dash): NU-WRF with LIS

- MRMS as reference data
- Based on 3 hours accumulation (mm)
- NAM has low Bias, high RMSE, and low correlation compare with NU-WRF.
- WRF has high bias, low RMSE, and high correlation compare with COUP.

MC3E Real-time forecast



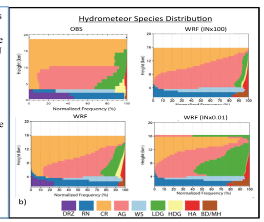
Three nested domain (**18km, 6km, 2km**) with **40 vertical layers**.

Physics: Goddard Microphysics scheme, Grell-Devenyi ensemble cumulus scheme, Goddard Radiation schemes, MYJ planetary boundary layer scheme, Noah surface scheme, Eta surface layer scheme.

Computational Cost: **240 CPUs, takes 4 hours to produce 48 hours forecast.**

WRF-SBM and Polarimetric Radar Observation in MC3E

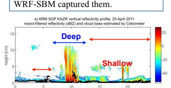
1. Hydrometeor distributions from WRF-SBM simulations were first time evaluated against the CSU Polarimetric HID retrievals.
2. WRF-SBM closely generate 9 different hydrometeor species to the polariemtric retrievals including heavily rimed particle.
3. Distributions is highly sensitive to the ice-formulating nuclei.

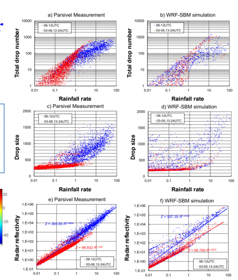


Dolan, B., T. Matsui, A. A. Matthews, S. A. Rutledge, W. Xu, W.-K. Tao, T. Iguchi, V. Chandrasekar (2014), Multi-sensor Radar Observations and Size-Resolving Cloud Modeling Analysis of the 25 April 2011 MC3E Convective Case, (submitted to MWR)

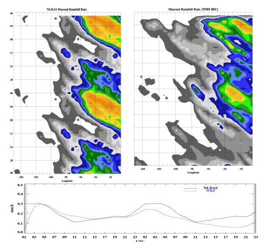
Parsivel disdrometer measurements – WRFSBM simulations

- Ka-band zenith radar and Parsivel disdrometers on ARM SGP site revealed two distinct modes of DSD in shallow and deep convective clouds within one-day rainfall event, and WRF-SBM captured them.





Diurnal Variation (April 20-June 3, 2011)



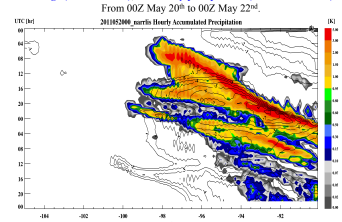
Time series of WRF model-estimated domain mean surface rainfall rate (mm h^{-1}). The observation is also shown for comparison.

The model simulated diurnal variation of rainfall captures observed well. For example, two peaks at 05 UTC and 03 UTC are simulated.

The propagating of the precipitating system is the main reason for diurnal variation of rainfall.

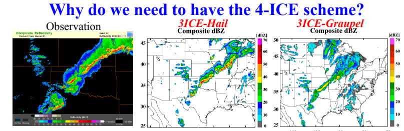
Tao, W.-K., D. Wu, T. Matsui, S. Lang, C. Peters-Lidard, A. Hou, M. Rienecker, W. Petersen, and M. Jensen, 2013: The Diurnal Variation of Precipitation: A numerical modeling study, *J. Geophys. Res.*, Atmos.,**118**, 7199–7218, doi:10.1002/jgrd.50410. http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50410/abstract

Time-longitude diagram for **deviation of virtual potential temperature from the domain average (filled contour)**, and **hourly precipitation (over laid in black)**. From 00Z May 20th to 00Z May 22nd.



Close relationship between cool pool and rainfall
Cool pool boundary is ahead of intense rainfall

Why do we need to have the 4-ICE scheme?

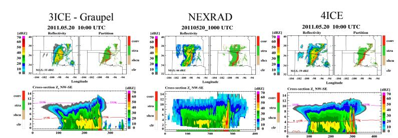


Almost all microphysics schemes are 3-ICE (cloud ice, snow and graupel). Very few 3ICE schemes have the option to have hail processes (cloud ice, snow, graupel or hail)

Both hail and/or graupel can occur in real weather events simultaneously, therefore a 4ICE scheme (cloud ice, snow, graupel and hail) is required for real time forecasts (especially for high-resolution prediction of severe local thunderstorms, mid-latitude squall lines and tornadoes)

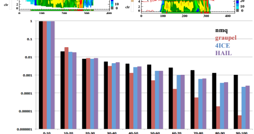
Current and future **global high-resolution cloud-resolving models need the ability to predict/simulate a variety of weather systems** from weak to intense (i.e., tropical cyclones, thunderstorms) **over the globe**; this requires the use of a 4ICE scheme

Lang, S., W.-K. Tao, J.-D. Chern, D. Wu, and X. Li, 2014: Benefits of a 4th ice class in the simulated radar reflectivities of convective systems using a bulk microphysics scheme, *J. Atmos. Sci.*,**71**, 3583-3612.



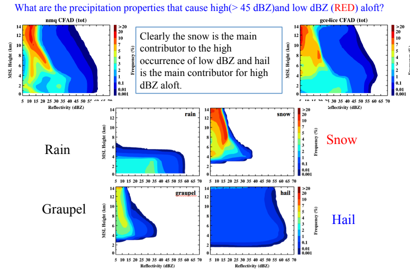
PDF – Rainfall Intensity >

Both 4ICE and 3ICE-Hail simulated more heavy rainfall than 3ICE-Graupel



Tao, W.-K., D. Wu, S. Lang, J. Chern, A. Fridlind, C. Peters-Lidard, T. Matsui, 2014: High-resolution model simulations of MC3E deep convective-precipitation systems: Part I: Comparisons between Goddard microphysics schemes and observation. *J. Geophys. Res.*, (submitted)

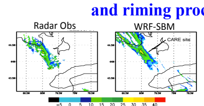
What are the precipitation properties that cause high(> 45 dBZ)and low dBZ (RED) aloft?



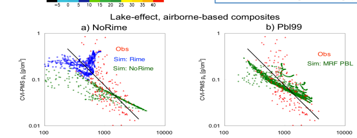
Clearly the snow is the main contributor to the high occurrence of low dBZ and hail is the main contributor for high dBZ aloft.

Individual contribution of precipitating particles (rain, snow, graupel and hail) on the CFADs for 4ICE case

Sensitivity of PBL to super-cooled water and riming process in C3VP



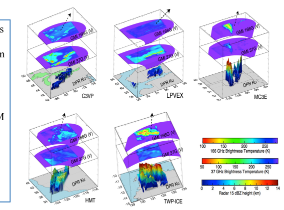
1. WRF-SBM captured structure of lake-effect snow storm.
2. Detailed analysis of SBM microphysics and aircraft observations revealed the large sensitivity of PBL scheme to mixed-phase microphysics.



Iguchi T., T. Matsui, J. J. Shi, W.-K. Tao, A. P. Khain, A. Hou, R. Cifelli, A. Heymsfield, and A. Tokay (2012), Numerical analysis using WRF-SBM for the cloud microphysical structures in the C3VP field campaign: Impacts of supercooled droplets and resultant riming on snow microphysics, *Journal of Geophyiscal Research*, 117, D23206, doi:10.1029/2012JD018101.

Synthetic GPM Simulator

1. WRF-SBM simulations were used to generate observable signals from the GPM satellite before launching.
2. Supporting algorithm development, and GPM simulator (forward model) will support CRM evaluation/ development and data assimilation.



Matsui, T. T. Iguchi, X. Li, M. Han, W.-K. Tao, W. Petersen, T. L'Ecuyer, R. Meneghini, W. Olson, C. D. Kummerow, A. Y. Hou, M. R. Schwaller, E. F. Stocker, J. Kwiatkowski (2013), GPM satellite simulator over ground validation sites, Bulletin of the American Meteorological Society 2013 ; e-View doi: http://dx.doi.org/10.1175/BAMS-D-12-00160.1

Summary and Future Works

•NU-WRF simulations can capture the basic characteristics of mid-latitude and high-latitude precipitation events.

•The Goddard 4-ICE scheme significantly improves the structure, CFADs (especially for higher dBZ aloft) compared to the 3-ice scheme.

•Continue to support GV by conduct NU-WRF real-time forecasting

•Continue to validate the model-simulated cloud microphysical properties using ground-based, space-borne and aircraft measurements – working with CSU radar group

•Compare different WRF microphysics schemes

•Conduct sensitivity tests to identify the uncertainty of some of the microphysical processes (i.e., riming) – currently is working with CSU RAMS group